

MATCHING, CONTRAST, AND EQUALIZING IN THE CONCURRENT LEVER-PRESS RESPONDING OF RATS¹

WAYNE D. NORMAN AND F. K. MCSWEENEY

WASHINGTON STATE UNIVERSITY

Five rats pressed levers for food reinforcers delivered by several concurrent variable-interval variable-interval schedules. The rate of reinforcement available for responding on one component schedule was held constant at 60 reinforcers per hour. The rate of reinforcement available for responding on the other schedule varied from 30 to 240 reinforcers per hour. The behavior of the rats resembled the behavior of pigeons pecking keys for food reinforcers. The ratio of the overall rates of responding emitted under, and the ratio of the time spent responding under, the two components of each concurrent schedule were approximately equal to the ratio of the overall rates of reinforcement obtained from the components. The overall rate of responding emitted under, and the time spent responding under, the variable component schedule varied directly with the overall rate of reinforcement from that schedule. The overall rate of responding emitted under, and the time spent responding under, the constant component schedule varied inversely with the overall rate of reinforcement obtained from the variable component. The local rates of responding emitted under, and the local rates of reinforcement obtained from, the two components did not differ consistently across subjects. But they were not exactly equal either.

Key words: matching law, behavioral contrast, equalizing principle, concurrent schedule, lever press, rats

Much research has investigated the behavior of pigeons pecking keys for food reinforcers delivered under concurrent schedules. Their behavior has been described in several ways. First, it has been found that the relative rate of responding generated by each component of a concurrent schedule equals the relative rate of reinforcement that the component provides. This is expressed by the Matching Law (Herrnstein, 1970). P_1 is the subject's rate of responding under component 1, which provides a rate of reinforcement equal to R_1 .

$$\frac{P_1}{P_1 + P_2} = \frac{R_1}{R_1 + R_2} \quad (1)$$

P_2 is the rate of responding generated by the other component, which provides a rate of reinforcement equal to R_2 . The rates are overall rates, calculated by dividing the number of responses emitted under, or the number

of reinforcers obtained from, each component schedule by the total session time minus the time for which food is presented.

Baum (1974) proposed a more general formulation of the Matching Law. B_1 and B_2

$$\frac{B_1}{B_2} = k \left(\frac{r_1}{r_2} \right)^a \quad (2)$$

are the behaviors emitted under components 1 and 2. They may be measured by the time spent engaging in them, as well as by their rates of occurrence (Baum and Rachlin, 1969). The variables r_1 and r_2 are the values of the reinforcers obtained from components 1 and 2. The amount, immediacy, and rate of presentation of a reinforcer contribute to its value. Rates of behaviors and of reinforcement are calculated as they were in Equation (1). The parameters k and a express deviations from the Matching Law called bias and undermatching, respectively. Equation (3) shows that Herrnstein's law is a special case of Equation (2), in which k and a are equal to 1.0.

$$\frac{\frac{P_1}{P_1 + P_2}}{\frac{P_2}{P_1 + P_2}} = \frac{\frac{R_1}{R_1 + R_2}}{\frac{R_2}{R_1 + R_2}} = \frac{P_1}{P_2} = 1.0 \left(\frac{R_1}{R_2} \right)^{1.0} \quad (3)$$

¹This study was submitted by Wayne D. Norman to the Department of Psychology at Washington State University in partial fulfillment of the requirements for the degree Master of Science in Psychology. The data were presented at the 1976 meeting of the Psychonomic Society. Reprints may be obtained from F. K. McSweeney, Department of Psychology, Washington State University, Pullman, Washington 99163.

Second, studies have reported that the overall rate of responding emitted under a component schedule varies directly with the overall rate of reinforcement obtained from that component, and inversely with the overall rate of reinforcement obtained from the other component (Catania, 1963; McSweeney, 1975*b*). The inverse relation has been called behavioral contrast.

Rachlin (1973) proposed that the proportion of the total session time spent responding under a component schedule also varies directly with the overall rate of reinforcement obtained from that component, and inversely with the overall rate of reinforcement obtained from the other component. Rachlin noted that Equation (4) describes the overall rate of responding generated by a component of a concurrent schedule.

$$P_1 = \frac{P_1}{T} = \frac{P_1}{T_1} \cdot \frac{T_1}{T} \quad (4)$$

That is, the overall rate of responding (the number of responses emitted divided by the total session time, p_1/T) is the mathematical product of the local rate of responding emitted under that component (the number of responses emitted divided by time spent responding under that schedule, p_1/T_1), and the proportion of the total session time spent responding on that schedule (T_1/T). Theoretically, changes in the overall rate of responding could be produced by changes in either variable. But, Rachlin argued that the proportion of the total session time spent responding under a component increases with increases in the rate of reinforcement obtained from the component. The increase in the proportion of time spent responding under one component produces a decrease in the proportion of the total session time spent responding under the other component. According to Rachlin, the local rates of responding generated by the component schedules remain constant, and equal to each other, in spite of changes in the rate of reinforcement provided by either component.

Third, it has been reported that pigeons distribute their time between the components of a concurrent schedule so that the local rates of reinforcement obtained from the two component schedules will be equal (Killeen, 1972). This finding has been called the equalizing principle. Again, local rates of reinforcement

are calculated by dividing the number of reinforcers obtained from each component by the time spent responding under that component schedule.

The present study asks whether the behavior of rats pressing levers under concurrent schedules resembles the behavior of pigeons pecking keys under concurrent schedules. Two past studies have examined this question. Shull and Pliskoff (1967) found that the relative rate of responding emitted under, and the relative time spent responding under, the components of two concurrent schedules obeyed the Matching Law when long changeover delays (COD) penalized switches between the components. The changeover delay was a period of time during which no responses were reinforced and was initiated by all switches from one lever to the other. Baum (1976) found that the rates of responding emitted under, and the time spent holding the levers associated with, the components of several concurrent schedules, obeyed the Matching Law and showed behavioral contrast.

The present study extends these results. It examined the equalizing principle, as well as the Matching Law and behavioral contrast, using a procedure that closely resembles those used when pigeons serve as subjects. The studies by Shull and Pliskoff, and by Baum differed from those that have employed pigeons in a number of ways. Shull and Pliskoff used brain stimulation, rather than food as the reinforcer, and they manipulated the relative rate of reinforcement by manipulating the duration of the COD, rather than by manipulating the scheduled rate of reinforcement. Baum recorded and reinforced the amount of time that the rats spent holding the levers. Studies that have used pigeons have reinforced discrete responses and have recorded the amount of time the subjects spend responding on one key without changing to the other. However, these studies have not recorded the amount of time the subjects spent pressing the key.

METHOD

Subjects

Five experimentally naive, male hooded rats, bred at Washington State University, were approximately four months old at the beginning of the experiment.

Apparatus and Procedure

Subjects, maintained at approximately 90% of their free-feeding weights, were placed in a standard Grason-Stadler, model E3125D-100 two-lever, experimental enclosure for rats. The enclosure was located in a sound-attenuating chamber. White noise was present in the chamber at all times. Pressing each of the response levers was shaped by a successive approximations procedure. The levers were located to the right and left, above the food cup and were operated by a force of approximately 0.20 N. A houselight, located above and to the right of the wall containing the food cup, was illuminated throughout the session.

When the shaping procedure had been completed, the rates of reinforcement provided by the two levers were gradually decreased until the subjects responded under a concurrent variable-interval 1-min, variable-interval 1-min (*conc* VI 1-min VI 1-min) schedule. This procedure continued until subjects responded at a rate that was approximately equal for the two component schedules. A changeover delay (COD) of 1 sec was initially introduced and gradually increased to 5 sec, where it remained for the rest of the experiment. The COD was a period of time during which no reinforcers were collected and was initiated by all switches from one lever to the other. The 5-sec COD duration was selected because at this value the rates of responding and the time spent responding under the component schedules did not deviate from the Matching Law consistently across subjects. Past research has shown that behavior approaches the Matching Law as duration of the COD increases (Shull and Pliskoff, 1967). Additional increases in duration have no reported effect.

Subjects were placed under a series of concurrent schedules after responding under the *conc* VI 1-min VI 1-min schedule had become stable. The schedules studied and the number of sessions for which each schedule was in effect appear in Table 1 in the order in which they were presented. The component schedule listed first was that associated with the lever located to the subject's right as it faced the wall containing the food cup. The component associated with the lever to the subject's left appears second. The locations of the levers were the only discrimina-

tive stimuli arranged by the experimenter for the component schedules. Interreinforcer intervals for all schedules were arranged according to a 12-interval series, constructed by a procedure outlined by Catania and Reynolds (1968, p. 381). The delivery of one 45-mg Noyes food pellet served as reinforcement.

Responding under each concurrent schedule was considered to be stable when the overall rates of responding emitted during the last five sessions fell within the range of rates of responding set by the earlier sessions. Sessions were conducted daily, six to seven times per week. Each session terminated when 40 reinforcers had been delivered.

RESULTS

The Matching Law

Figure 1 displays the logs of the ratios of the overall rates of responding generated by, and the logs of the ratios of the amounts of time spent responding under, the two components of each concurrent schedule, plotted as a function of the logs of the ratios of the overall rates of reinforcement that the components provided. Overall rates were calculated by dividing the number of responses emitted under, or the number of reinforcers obtained from, each component schedule by the total session time. The time spent responding under a component schedule was measured by a timer that began when the subject made its first response under that component. The timer stopped, and the timer for the other component began, with the next response emitted under that component. Table 2 shows the values from which the data in Figure 1 were obtained.

The subjects obeyed the Matching Law as stated by Baum, and they did not systemati-

Table 1

The number of sessions for which each schedule was conducted in order of presentation.

	Schedule		Subject				
	Right Lever	Left Lever	1	2	3	4	5
<i>conc</i>	VI 1-min	VI 1-min	28	38	33	31	41
<i>conc</i>	VI 15-sec	VI 1-min	27	15	22	22	21
<i>conc</i>	VI 30-sec	VI 1-min	30	36	36	33	32
<i>conc</i>	VI 1-min	VI 2-min	20	21	28	25	25
<i>conc</i>	VI 1-min	VI 1-min	29	31	35	33	28

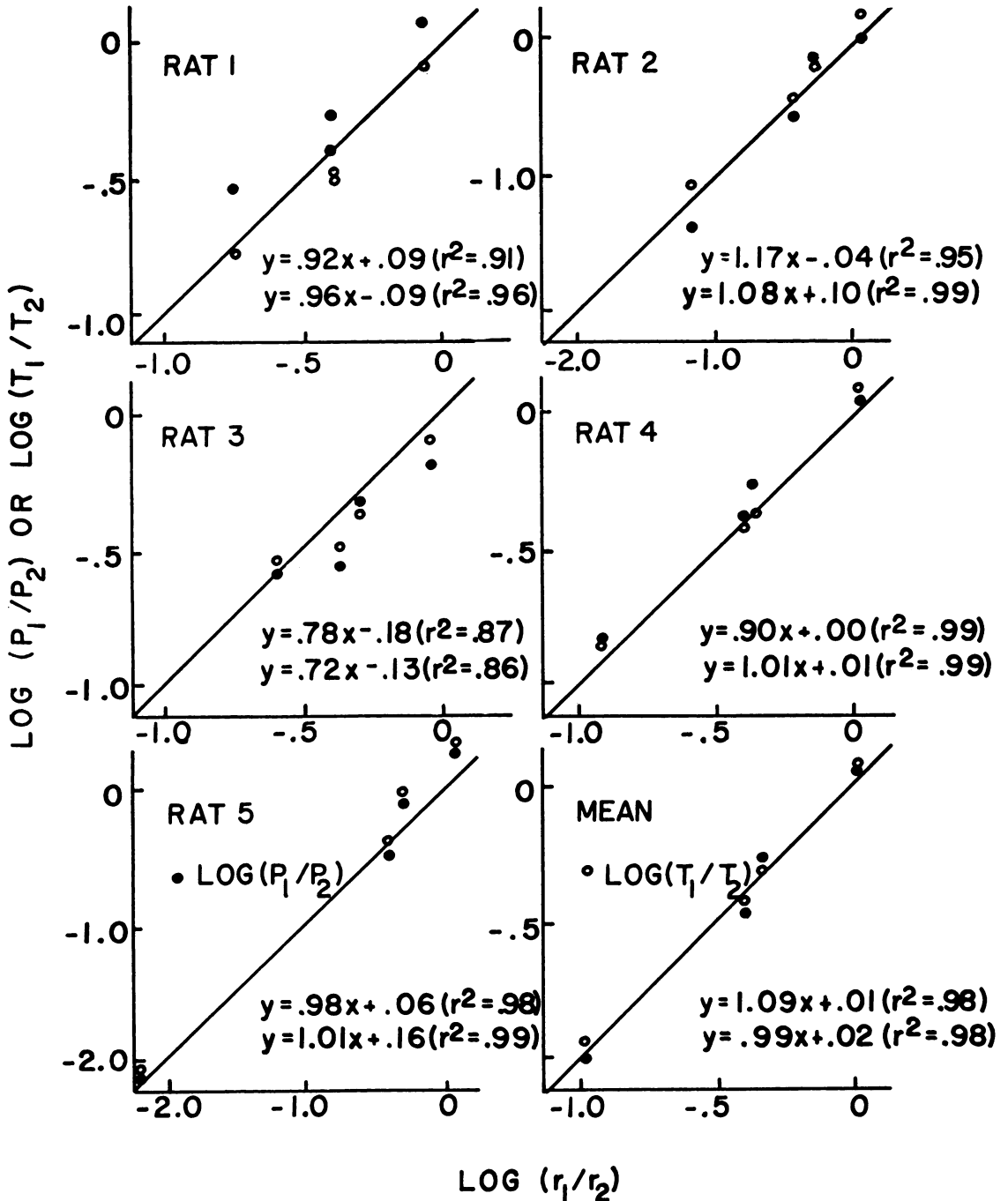


Fig. 1. Logs of the ratios of the overall rates of responding emitted under (P_1/P_2), and logs of the ratios of the time spent responding under (T_1/T_2), the two components of each concurrent schedule, plotted as a function of the logs of the ratios of the overall rates of reinforcement obtained from the components (r_1/r_2). The sixth set of axes contains the mean of the data generated by all subjects. Each of the other sets of axes represents the data generated by a single subject. Each point is the mean of the values generated over the last five sessions for which each schedule was presented. The points obtained from the two presentations of the *conc* VI 1-min VI 1-min schedule have been averaged. A least-squares procedure has been used to calculate the equations for the best-fitting straight lines for the response rates and time spent responding. These equations, and the proportion of the variance in the data accounted for by the lines, appear on the Figure. The equations for the response ratios appear above the equations for the time ratios.

Table 2
Proportion of the total session time spent responding under, overall rate of responding generated by, and overall rate of reinforcement obtained from, each component of each concurrent schedule; the standard errors appear in parentheses. All statistics have been calculated over the last five sessions for which the schedule was available.

Rat	VI 15-sec	VI 1-min	VI 30-sec	VI 1-min	VI 1-min	VI 2-min	VI 1-min	VI 1-min
1								
proportion of time		0.14 (0.01)	0.75 (0.01)	0.25 (0.01)	0.77 (0.01)	0.23 (0.01)	0.56 (0.02)	0.44 (0.02)
responses	0.86 (0.01)	9.1 (0.51)	34.0 (0.34)	18.5 (1.74)	28.1 (1.14)	11.5 (0.83)	23.5 (3.97)	28.5 (1.05)
reinforcement	32.8 (0.81)	37.2 (5.36)	106.8 (2.49)	43.4 (2.70)	58.9 (1.05)	24.1 (1.49)	56.8 (1.33)	47.7 (1.33)
2								
proportion of time	0.93 (0.00)	0.07 (0.00)	0.75 (0.01)	0.25 (0.01)	0.61 (0.04)	0.39 (0.04)	0.37 (0.04)	0.63 (0.04)
responses	140.4 (3.82)	4.4 (0.80)	57.5 (6.27)	15.2 (1.96)	24.7 (2.67)	16.5 (1.37)	28.0 (5.93)	27.2 (3.96)
reinforcement	241.2 (4.09)	18.0 (1.45)	92.6 (5.25)	38.6 (2.09)	52.6 (2.38)	26.9 (0.99)	43.3 (3.23)	53.0 (1.87)
3								
proportion of time	0.79 (0.01)	0.21 (0.01)	0.76 (0.01)	0.24 (0.01)	0.71 (0.01)	0.29 (0.01)	0.55 (0.04)	0.45 (0.04)
responses	60.5 (2.58)	11.7 (0.80)	53.4 (2.36)	14.2 (0.63)	36.3 (1.24)	16.0 (0.70)	34.3 (3.16)	22.3 (0.86)
reinforcement	202.2 (5.91)	39.6 (3.83)	99.7 (3.04)	43.5 (1.08)	60.2 (1.18)	28.0 (1.43)	53.9 (1.42)	49.6 (2.15)
4								
proportion of time	0.88 (0.01)	0.12 (0.01)	0.73 (0.02)	0.27 (0.02)	0.70 (0.02)	0.30 (0.02)	0.45 (0.04)	0.55 (0.04)
responses	46.8 (1.46)	6.8 (0.83)	33.4 (1.26)	13.7 (0.87)	24.0 (0.52)	13.3 (0.73)	21.5 (3.07)	22.2 (1.11)
reinforcement	224.6 (6.96)	27.6 (4.50)	106.7 (3.03)	41.2 (1.51)	60.0 (0.33)	26.5 (1.40)	49.8 (2.79)	54.5 (2.08)
5								
proportion of time	0.99 (0.01)	0.01 (0.01)	0.72 (0.02)	0.28 (0.02)	0.54 (0.01)	0.46 (0.01)	0.30 (0.01)	0.70 (0.01)
responses	74.6 (2.85)	0.5 (0.42)*	45.8 (1.37)	12.7 (0.74)	27.9 (0.71)	19.1 (0.35)	16.3 (1.07)	31.9 (0.67)
reinforcement	242.4 (2.35)	1.2 (1.20)*	106.1 (3.14)	42.2 (1.59)	55.8 (1.65)	28.9 (1.77)	45.8 (1.93)	60.4 (0.75)
mean								
proportion of time	0.89 (0.03)	0.11 (0.03)	0.73 (0.01)	0.27 (0.01)	0.67 (0.04)	0.33 (0.04)	0.45 (0.04)	0.55 (0.04)
responses	71.0 (18.69)	6.5 (1.94)	44.8 (4.91)	14.9 (0.98)	28.2 (2.18)	15.3 (1.32)	24.7 (4.16)	26.4 (2.17)
reinforcement	224.6 (7.86)	24.6 (7.01)	102.4 (2.77)	41.8 (0.90)	57.5 (1.47)	26.9 (0.81)	49.9 (2.50)	53.0 (2.20)

*Three of five observations had a score of zero.

cally violate Herrnstein's version of the Law. Taking the logs of both sides of Equation 2 shows that the function presented in Figure 1 should be linear if Baum's theory is correct. The slopes of these lines will equal the a parameter, and the y-intercept will equal the log of the k parameter. Baum's equation accounted for 87 to 99% of the variance in the ratios of the rates of responding, and from 86 to 99% of the variance in the time spent responding on the components.

Equation 3 shows that Herrnstein's formula is a special case of Baum's equation, in which k and a parameters equal 1.0. Herrnstein's equation is represented by the diagonal lines drawn in Figure 1. The points do not fall exactly on the line, but they do not deviate from it in a way that is consistent across subjects. The values of the a parameter varied from 0.78 to 1.17 for the ratios of the rates of responding, and from 0.72 to 1.08 for the ratios of the time spent responding. Deviations from 1.0 were in different directions for different subjects. The y-intercepts of the lines, which are the logs of the k parameters, varied from -0.18 to 0.09 and from -0.13 to 0.16 for the ratios of the rates of responding and the time spent responding, respectively. The values of k were 1.23, 0.91, 0.66, 1.00, and 1.15 for the response ratios, and 0.81, 1.26, 0.74, 1.02, and 1.45 for the time ratios, for Rats 1 to 5 respectively. Again, k was not systematically different from 1.0 across subjects.

Overall Rate of Responding, Proportion of Time Spent Responding, and Overall Rate of Reinforcement

Figure 2 contains the overall rate of responding emitted under (top section), and the proportion of the total session spent responding under (bottom section), the variable component schedule, plotted as a function of the overall rate of reinforcement obtained from that component. The variable component provided the variable scheduled rate of reinforcement. Figure 2 shows that the overall rate of responding emitted under, and the proportion of the total session time spent responding under, the variable component schedule increased with increases in the rate of reinforcement obtained from that component.

Figure 3 contains the overall rate of responding emitted under (top section), the proportion of the total session time spent re-

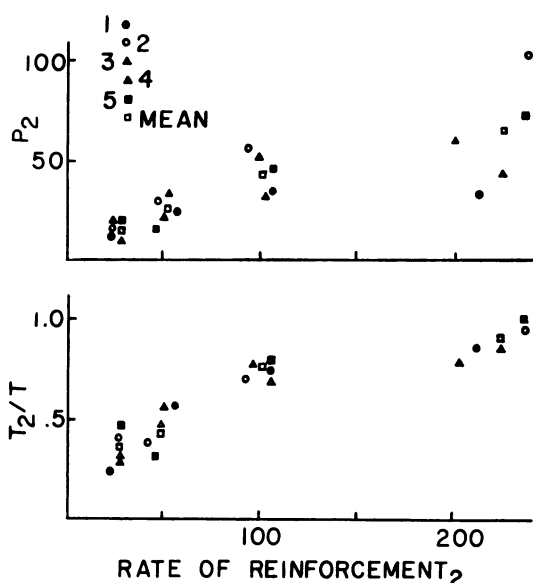


Fig. 2. Overall rate of responding emitted under (top section), and proportion of total session time spent responding under (bottom section), the variable component schedule plotted as a function of the overall rates of reinforcement obtained from that component. Each point is the mean of the values generated over the last five sessions for which each schedule was presented. The points obtained from the two presentations of the *conc* VI 1-min VI 1-min schedule have been averaged. Rates of responding have been reported in responses per minute; rates of reinforcement, in reinforcers per hour.

sponding under (middle section), and the overall rate of reinforcement obtained from (bottom section), the VI 1-min component, plotted as a function of the overall rate of reinforcement obtained from the variable component. Figure 3 shows that behavioral contrast did occur. The top and middle sections show that the overall rate of responding emitted under, and the proportion of the total session time spent responding under, the VI 1-min component decreased as the overall rate of reinforcement obtained from the variable component increased. The bottom section shows that the overall rate of reinforcement obtained from the VI 1-min component schedule also decreased with increases in the rate of reinforcement obtained from the variable component schedule.

The Equalizing Principle

Figure 4 contains the ratios of the local rates of responding emitted under, and the ratios of the local rates of reinforcement obtained from

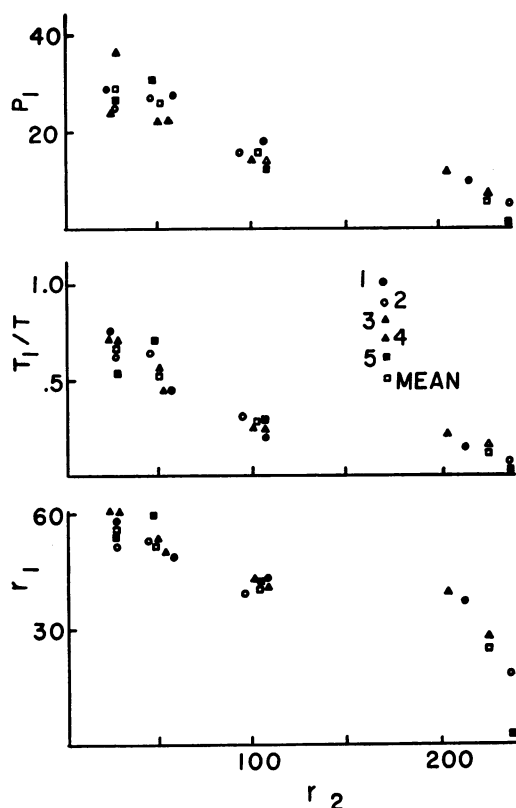


Fig. 3. Overall rate of responding emitted under (top section), proportion of total session time spent responding under (middle section), and overall rate of reinforcement obtained from (bottom section) the VI 1-min component schedule, plotted as a function of the overall rate of reinforcement obtained from the other component (r_2). Each point is the mean of the values obtained from the last five sessions for which the schedule was presented. The points obtained from the two presentations of the *conc* VI 1-min VI 1-min schedule have been averaged. Rates of responding have been reported in responses per minute; rates of reinforcement, in reinforcers per hour.

the two components of each concurrent schedule, plotted as a function of the overall rate of reinforcement obtained from the variable component. Local rates were calculated by dividing the number of responses emitted under, or the number of reinforcers obtained from, each component by the time spent responding on that component. All of the points that represent the ratios of the local rates of responding would fall on the horizontal line at 1.0 if the rates of responding generated by the components of each schedule were exactly equal. All points that represent the ratios of the local rates of reinforcement would fall on

the horizontal line at 1.0 if the subjects exactly obeyed the equalizing principle.

The points plotted in Figure 4 do not violate the equalizing principle or the equality of the local rates of responding in a way that is consistent across subjects. The points fall above the line approximately as often as they fall below it; however, the data do not provide strong support for equality either. First, the values of individual ratios differ substantially from 1.0. The ratios of the rate of responding vary from 0.57 to 2.87 for individual subjects, and from 1.05 to 1.49 for the mean of all subjects. The ratios of the rates of reinforcement vary from 0.62 to 6.07 for individual subjects, and from 0.88 to 1.32 for the mean of all subjects. Second, the ratios of the rates of responding change systematically with changes in the rate of reinforcement obtained from the variable component for individual subjects. The ratios of the rates of responding increase consistently with increases in reinforcement for Rats 2, 3, and 5. They decrease consistently with increases in reinforcement for Rats 1 and 4.

DISCUSSION

The Matching Law

The data conform closely to Baum's version of the Matching Law. Baum's equation accounts for 87 to 99% of the variance in the rates of responding, and for 86 to 99% of the variance in the time spent responding.

The data presented in Figure 1 do not violate Herrnstein's version of the Law consistently across subjects. Herrnstein's formula is a special case of Baum's equation, in which the k and a parameters equal 1.0. The values of k and a were not exactly equal to 1.0, but they were not consistently greater than or less than 1.0 either.

However, Figure 4 shows that Herrnstein's Matching Law may not be a good description of the behavior of individual subjects. Figure 4 presents the ratios of the local rate of responding emitted under, and the ratios of the local rates of reinforcement obtained from, the two components of the concurrent schedules, plotted as a function of the overall rate of reinforcement obtained from the variable component. The local rates of reinforcement must be equal if the ratios of the time spent responding on the components exactly obey

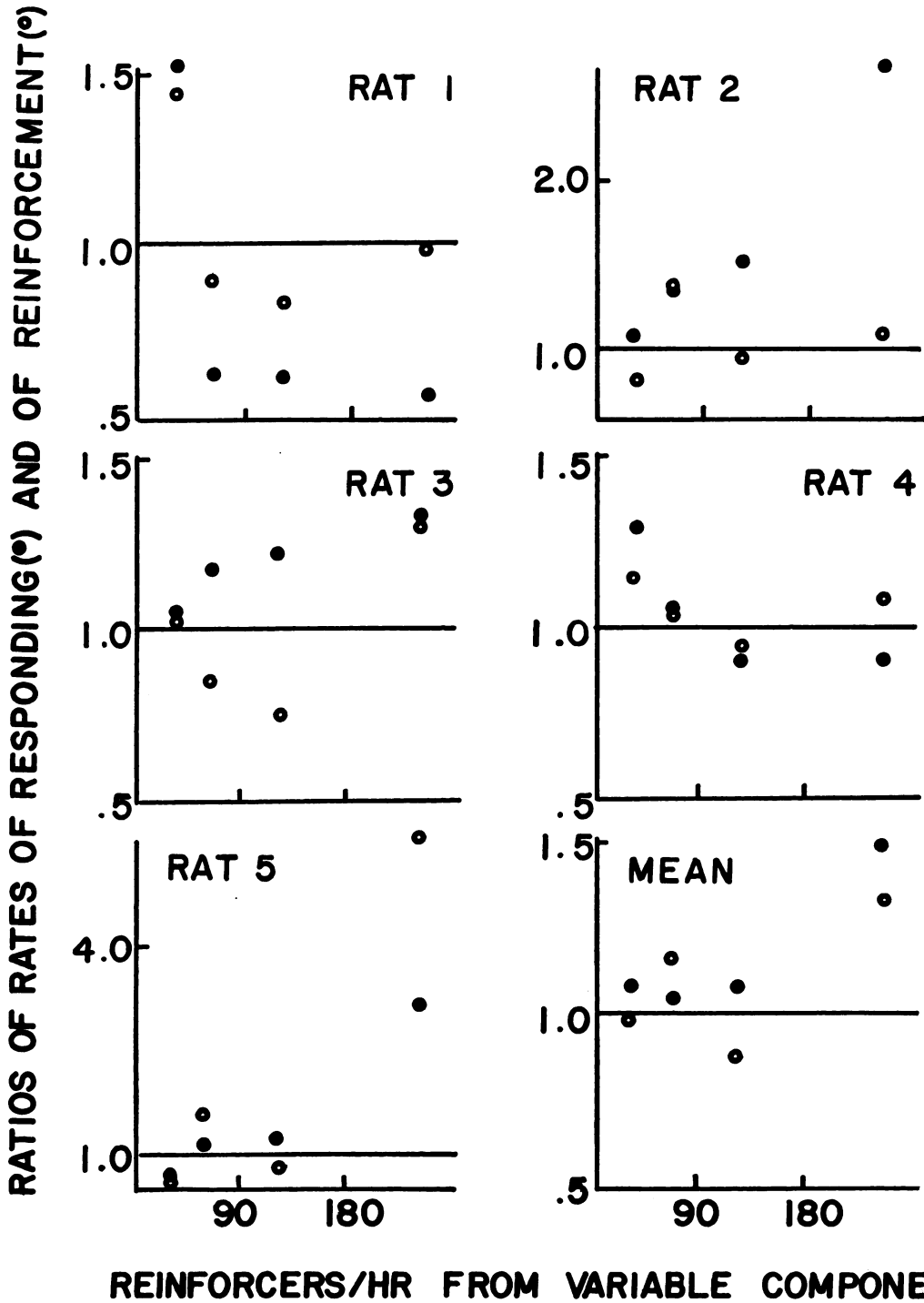


Fig. 4. Ratios of the local rates of responding emitted under, and ratios of the local rates of reinforcement obtained from, the two components of each concurrent schedule, plotted as a function of the rate of reinforcement scheduled for the variable component. All points are the means of the rates generated over the last five sessions for which the schedule was available. The data obtained from the two presentations of the *conc* VI 1-min VI 1-min schedule have been averaged. The statistic for the variable component schedule has been divided by the statistic for the VI 1-min component.

Herrnstein's Matching Law. That is, $T_1/T_2 = r_1/r_2$ implies that $r_1/T_1 = r_2/T_2$. The local rates of responding must be equal if the ratios of the rates of responding and the ratios of the time spent responding obey Herrnstein's version of the Matching Law. That is, $P_1/P_2 = r_1/r_2$ and $T_1/T_2 = r_1/r_2$ imply that $P_1/P_2 = T_1/T_2$, which implies that $P_1/T_1 = P_2/T_2$ and $p_1/T_1 = p_2/T_2$. Therefore, the deviations from the equality of the local rates of responding and from the equality of the local rates of reinforcement, which appear in Figure 4, also represent systematic deviations from Herrnstein's version of the Matching Law. The results presented in Figure 4 are consistent with those presented in Figure 1. The deviations from equality do not occur in a way that is consistent across subjects. But the results presented in Figure 4 do add to those presented in Figure 1. They suggest that individual subjects may deviate systematically from the Law.

The results presented in Figure 4 deserve further study. Conclusions about systematic trends in the data generated by individual subjects should be based on more than four points per subject. This is particularly true in the present case. Many of the points in Figure 4 do not fall outside of the ranges of the ratios that produced the other points. The study that replicates these results should employ a longer changeover delay. Past studies have shown that the duration of the COD may determine how well the Matching Law describes the data (Shull and Pliskoff, 1967). Therefore, a study that employed a longer COD might produce closer conformity to Herrnstein's version of the Law. The factors that produce systematic deviations from Herrnstein's Matching Law should be investigated if the present results are replicated in a study that presents more schedules and uses a longer COD.

Overall Rate of Responding, Proportion of Time Spent Responding, and Overall Rate of Reinforcement

Figures 2 and 3 show that the overall rate of responding emitted under, and the proportion of the total session time spent responding under, the component schedules varied directly with the overall rate of reinforcement provided by that component, and inversely with the overall rate of reinforcement provided by the other component schedule. The inverse

relation extends the generality of behavioral contrast, and it supports one of the predictions of Rachlin's theory (Rachlin, 1973). As argued earlier, Rachlin's theory states that subjects will increase the proportion of the total session time they spend responding on one component schedule when the rate of reinforcement provided by the other component schedule decreases. The middle section of Figure 2 clearly confirms this prediction.

The bottom section of Figure 3 suggests that the behavioral contrast found in this experiment may be a byproduct of the relation between the rate of responding emitted on the VI 1-min component and the rate of reinforcement obtained from that component. It shows that the rate of reinforcement obtained from the VI 1-min component schedule varied inversely with the rate of reinforcement obtained from the variable component. The overall rates of responding emitted under, and the proportion of the total session time spent responding under, the VI 1-min component varied directly with the rate of reinforcement provided by that component.

The inverse relation between the overall rates of reinforcement supplied by the component schedules deserves further study. First, experiments should determine the generality of this finding. For example, it is not known whether the same function would be found when pigeons respond under concurrent schedules. The rates of reinforcement obtained from the component schedules have not always been reported when pigeons have served as subjects. One study that did report them did not find an inverse relation (McSweeney, 1975b). Second, experiments should investigate the relation of this finding to behavioral contrast. Figure 3 shows that the rate of responding emitted on the VI 1-min component decreased as the rate of reinforcement obtained from the variable component increased. Experiments should investigate whether changes in the rate of reinforcement obtained from the VI 1-min component produced the changes in the rate of responding emitted under that component, or whether changes in the rate of responding produced the changes in the rate of reinforcement. Third, experiments should determine the factors that produce differences between the rates of reinforcement scheduled by the experimenter and the rates obtained by the sub-

jects. Discrepancies between the two rates have been reported in past studies (e.g., McSweeney, 1975a); however, the factors that produce these discrepancies have not been investigated.

The Equalizing Principle

The data presented in Figure 4 do not deviate from the equalizing principle or from Rachlin's prediction that the local rates of responding should be equal and constant across changes in the rates of reinforcement in a way that is consistent across subjects. But, the equalizing principle and Rachlin's prediction do not provide a good quantitative description of the data. The ratios of the local rates of responding and the ratios of the local rates of reinforcement differ substantially from 1.0, and the individual subjects may violate Rachlin's prediction in a systematic way. The ratios of the local rates of responding may increase with increases in the overall rates of reinforcement obtained from the variable component for Rats 2, 3, and 5. They may decrease systematically for Rats 1 and 4. As discussed earlier, these results should be replicated before any conclusions are drawn. Studies should be conducted for pigeons as well as rats. Few data support the principle or Rachlin's prediction when either species of animals serves as subjects.

REFERENCES

- Baum, W. M. On two types of deviation from the Matching Law: bias and undermatching. *Journal of the Experimental Analysis of Behavior*, 1974, **22**, 231-242.
- Baum, W. M. Time-based and count-based measurement of preference. *Journal of the Experimental Analysis of Behavior*, 1976, **26**, 27-35.
- Baum, W. M. and Rachlin, H. C. Choice as time allocation. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 861-874.
- Catania, A. C. Concurrent performances: reinforcement interaction and response independence. *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 253-263.
- Catania, A. C. and Reynolds, G. S. A quantitative analysis of the responding maintained by interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 327-383.
- Herrnstein, R. J. On the Law of Effect. *Journal of the Experimental Analysis of Behavior*, 1970, **13**, 243-266.
- Killeen, P. A yoked-chamber comparison of concurrent and multiple schedules. *Journal of the Experimental Analysis of Behavior*, 1972, **18**, 13-22.
- McSweeney, F. K. Concurrent schedule responding as a function of body weight. *Animal Learning and Behavior*, 1975, **3**, 264-270. (a)
- McSweeney, F. K. Matching and contrast on several concurrent treadle-press schedules. *Journal of the Experimental Analysis of Behavior*, 1975, **23**, 193-198. (b)
- Rachlin, H. C. Contrast and matching. *Psychological Review*, 1973, **80**, 217-234.
- Shull, R. L. and Pliskoff, S. S. Changeover delay and concurrent schedules: some effects on relative performance measures. *Journal of the Experimental Analysis of Behavior*, 1967, **10**, 517-527.

Received 28 July 1976.

(Final acceptance 30 November 1977.)